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Proactive Planning and Cost Scheduling to Reduce Critical Increases

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BY
JESPER KRANKER LARSEN

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AALBORG UNIVERSITY
DENMARK

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ENGLISH SUMMARY

This Ph.D. thesis is the outcome of a three years long research project at the Department of Mechanical and Manufacturing Engineering, Aalborg University. Entitled Streamlining Publicly Funded Construction Projects by Proactive Planning and Cost Scheduling to Reduce Critical Increases. Concerning the positive relationship between efforts applied in pre-project planning activities and the following level of project success at completion stage.

This research focus was applied due to the construction sector is one largest sectors at the private market. Nevertheless, the sector is one of the largest the labor productivity has only increased 10 % since 1966, where comparable countries such as Sweden, Germany and the Netherlands have increased as high as 100 % in the same period. The effect by apply proactive pre-planning principals in the construction sector appears to be a solution. Current research demonstrate an reduced project duration by up to 30 %, increased profit margins up to 25 %, reduced risk and budgets by 10 to 15 %, and lastly improved quality level between 5 to 10 % by applying pre-project planning.

To create a theoretical foundation a literature review, trend analysis, and co-pilot questionnaire were conducted to establish the research area. Interviews and document analysis of tender cases were conducted then to establish a research background, experiences, and state the problem more specific. In the problem foundation phase a questionnaire was used as a basis for defining constructs. Based on the questionnaire, theories and models of the reality were developed in the synthesis phase. To contribute with new innovation a multiple method was applied where data from the interviews and questionnaire were mixed. Lastly, in the "verification" phase a case study was conducted by applying observations, interviews, questionnaire, and simulation.

This research finds the level of effort applied to planning and scheduling activities in the initial phases particularly vital to reduce the probability for schedule and budget overruns. But at the same time also secure a higher level of contract required specifications and end-user satisfaction. Investing more effort in the initial project phases thus seems significant to secure success after completion. Nevertheless, it also uncovered that the largest difference between applying either a reactive or a proactive planning approach is not the level of success when completed. But the project manager and the organizations ability to handle unforeseen obstacles that makes the difference. Pre-planning must thus be considered as a process-oriented management approach, which increases the probability of securing contract agreed duration, budget, and quality.

This Ph.D. dissertation has been limited to study Danish state funded construction projects with a total project budget sum above the EU tendering threshold value for building and construction sector projects. Implementation of the results and recommendations from the dissertation will thus be directly applicable to state funded construction projects, but will also be applicable to less complicated construction projects in Denmark and similar countries. The reader is recommended to carefully consider the limitations of the results and recommendations if used outside the described research area.

DANSK RESUME

Denne Ph.d. afhandling er resultatet af et tre år langt forskningsprojekt ved Institut for Mekanik og Produktion, Aalborg Universitet med titlen: Streamlining Publicly Funded Construction Projects by Proactive Planning and Cost Scheduling to Reduce Critical Increases. Omhandlende sammenhængen mellem anvendt niveau af projektressourcer i opstartsfaserne og det efterfølgende niveau af succes ved projektets aflevering.

Dette forskningsfokus er anvendt idet byggesektoren er en af de største sektorer på det private Danske marked, men ikke desto mindre kun har haft produktivitetsstigninger på 10 % siden 1966, sammenlignet med omkringliggende lande som Sverige, Holland og Tyskland som har haft produktivitetsstigninger op til 100 % i samme tidsperiode. Anvendelse af principperne fra proaktiv planlægning i den Danske byggesektor kan derfor være en løsning på den manglende produktivitetsstigning. Aktuel forskning dokumenterer at op til 30 % reduceret projekt varighed, 25 % forøget profit margin, 10 til 15 % reducering af projekt risici og budget, samt 5 til 10 % forøget kvalitet er opnåligt ved anvendelse af proaktiv planlægning.

For at etablere et teoretisk fundament var litteratur studie, trend analyse, samt spørgeskema udarbejdet for etablering af forskningsfeltet. Interview og dokument analyse var herefter foretaget til etablering af forskningsbaggrund, erfaringer, samt konsolidering af det specifikke forskningsspørgsmål. I fasen for problemstilling blev et spørgeskema udarbejdet og målepunkter defineret. Baseret på skemaundersøgelsen var teorier og modeller udviklet i sammenstillingsfasen. Data fra interview og spørgeskema var herefter kombineret for at se mulige innovative perspektiver og bidrag. Et case studie var til sidst foretaget i verificeringsfasen hvor observering, interview, skemaundersøgelse og simulering blev anvendt.

Denne Ph.d. afhandling finder at et forøget niveau af planlægningsaktiviteter i opstartsfaserne af et projekt bidrager betydeligt til reduceret sandsynlighed for overskridelser af et projektets tid og økonomi. Det er samtidig fundet at dette også sikre et højre niveau af kontraktaftalt specifikationer samt slutbruger tilfredshed. Anvendelse af forøget ressourcer i opstartsfaserne af et projekt er derfor fundet væsentlig for at sikre et efterfølgende niveau af succes ved projektaflevering. Endvidere blev det også fundet at den største forskel på proaktiv og reaktiv planlægning ikke er niveauet af succes ved projektaflevering, men projektlederens og organisationens evne til at håndtere uforudsete komplikationer som afgør forskellen på projekt succes eller fiasko. Proaktiv planlægning må derfor betragtes som en proces orienteret ledelsesstil som forøger sandsynligheden for at kunne sikre kontraktaftalt projekt varighed, budget og kvalitet.

Afhandlingen er afgrænset til danske statslige finansierede byggeprojekter med en samlet projekt budgetsum over EU udbud tærskels værdi for bygge- og anlægsprojekter. Anvendelse af resultater og anbefalinger vil således være direkte anvendelige på statslige finansierede byggeprojekter, men vil også være egnet til mindre komplicerede byggeprojekter i Danmark og lignende lande. Læseren anbefales derfor nøje at overveje begrænsninger af resultaterne og anbefalingerne, ved anvendelse uden for det beskrevne forskningsområde.

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Aalborg, September 2015

Jesper Kranker Larsen

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CHAPTER 1. INTRODUCTION

1.1. IMPORTANCE OF THE RESEARCH FIELD

1.1.1. PROJECT COST ESCALATION

Insufficient project performance such as cost escalation in construction projects, time overruns and reduced quality level have been a frequently international experienced challenge for particularly the engineering and construction sector. Flyvbjerg et al. (2002) find transport infrastructure projects cost overrun not has decreased in the last 70 years with 28 % higher cost than estimated regardless of the infrastructure project type. And conclude that cost escalation frequency is best explained by strategic misrepresentation of the actual project context and its risk. Haimes (2005) further explain this cost escalation phenomena as the "buy-in game" with reference to the book *The Power Game: How Washington Works* by Hedrick (1988). Flyvbjerg et al. (2003) later discovers nine out of ten infrastructure projects experience cost escalations across 20 nations and on five continents. And state the results obtained on infrastructure projects cost challenges do not appear to be any different from other larger project types. Nicholas and Steyn (2012) supports this statement by describe that project cost escalations up to 20 % is relative common.

The reasons for such cost overruns are in general largely dependent of the geographical location and the level of economy for the country. However, Nicholas and Steyn (2012) describe that uncertainty and lack of accurate information, changes in requirements or design, economic and social factors, inefficiency, poor communication and lack of control, ego involvement from the estimator, project contract, and finally bias and ambition all stimulate project cost escalations regardless of geographical location or level of economy. Love (2002) find an average cost overrun at 12.7 % in construction projects and further demonstrate that 52.1 % of the cost overrun can be explained by rework based on design errors. Love (2002) and Lopez and Love (2011) further find closely similar mean results for direct (6.40 – 6.85 %) and indirect (5.60 – 7.36 %) rework costs from design errors. Finally Flyvbjerg et al. (2004) and Doloi (2013) are both stating that large project cost escalations mostly are signs of inefficiency in publicly funded projects.

The applied definition of a project cost escalation in this thesis is the gap between the forecasted total project cost at the decision time to start the project and the actual total accounted project cost after completion (Flyvbjerg et al. 2002).

1.1.2. PROJECT TIME ESCALATION

Time escalation and deviation from the planned time schedule is a frequently observed international challenge in the construction and engineering sector regardless of the countries level of economy (Kazaz et al. 2012). Assaf and Al-Hejji (2006) find 76 % of the contractors and 56 % of the consultants indicate an average time overrun for large construction project between 10 – 30 % of the original project duration. However, it is noteworthy that 25 % of the consultants indicated a higher range between 30 – 50 % average time overrun of the agreed deadline. Olawale and Sun (2010) find similar results between construction companies and project consultancies. 48.5 % of the respondents indicate a time overrun between 10

– 40 %, and 38.2 % experience increase less than 10 % finally 2.9 % of the respondents indicate a time overrun above 90 %. Hoffman et al. (2007) further discover 72 % of the military related projects not were completed according to in-house benchmark goals, 9 % of the cases exceeded deadline goals by more than two months, and 47 % were having overruns of more than four months.

Time overrun refers according to Kaliba et al. (2009) to a project that not is completed according to planned. Ahmed et al. (2002) argue there are a dependent relationship between the time plan, the scope and the conditions. Changing one or more of the three parameters thus affect the level of compensation between the three parameters and the project duration. Finally, Ahmed et al. (2002) find delay divided into four types (non-excusable delays[1], excusable non-compensable delays[2], excusable compensable delays[3] and concurrent delays[4]) based on how they are contractually organized. The consequence of extended duration beyond contract deadline is according to Al-Kharashi and Skitmore (2009) that it affects the project cost directly. Kazaz et al. (2012) argue similarly, but further notes that the effect at extended duration at the project cost also affects the resources allocated to construction inspection. Correspondingly, completion before contract agreed project deadline will likely increase total cost due to increased labor resources (Kazaz et al. 2012).

The applied definition of a project time escalation in this thesis is defined as a construction project that exceeded the agreed contract deadline or the date the partners have agreed up on for project delivery (O'Brien 1976). This definition is applied due to it is mostly applied in research literature by for example Lo et al. (2006) and Assaf and Al-Hejji (2006).

1.1.3. REDUCED PROJECT QUALITY

Reduced level of project quality, performance and productivity in the construction sector compared to other sectors is frequently criticized (Loushine et al. 2006). Jergeas et al. (2000) find 40 – 60 % of a construction worker´s day non-productive. Similar have Hewage and Ruwanpura (2006) demonstrated by 51 % of a workday used at value adding tool activates, and notes an substantial amount of time is spent at moving materials, idling and socializing (49 % of the time). Choy and Ruwanpura (2006) argue a 5 – 10 % increase in the time value adding activities will have significant cost savings for the construction projects and the sector. Park et al. (2010) studied scheduling decisions effect at project performance, and discover too aggressive planning, overtime working and resource adding effect the quality and productivity negative. Abdelsalam and Gad (2009) evaluated the cost of quality control in Dubai to 1.30 % of the project cost and find the optimum cost of quality is 1.34 % of the project sum. Finally, Abdelsalam and Gad (2009) demonstrate the failure cost was .7 % of the project budget. Kazaz et al. (2005) find the percentage of failure cost in total building project cost is between 2.3 – 9.4 % in Sweden

[1] Delays as a result of foreseeable factors in contractors control.
[2] Delays as a result of not-foreseeable factors beyond the contractor control.
[3] Delays as a result of project or owner related contract changes.
[4] Delay as a result of both owner and contractor responsibility.

(Josephson and Hammarlund 1999) and 15.0 % in UK (Bonshor and Harrison 1982). Finally, Kazaz et al. (2005) notes failure costs largely can be avoided with small investment in continues inspections and preventative action taking.

Total quality management or similar tools is according to Hoonakker et al. (2010) necessary to be implemented into the construction industry analogous to what the manufacturing industry have done. McIntyre and Kirschenman (2000) demonstrate by studying 1500 US construction firms that by applying total quality management a substantial economic tradeoff is obtainable. Similar results have been demonstrated by Liu (2003) who find significant lower errors and defects in publicly funded construction projects after applying ISO 9000 standardization than before. However, Hoonakker et al. (2010) note that some firms abandon implementation of total quality management due to the fact that it is too challenging to standardize *the nature of the construction process*, and find this culture as the largest barrier to successful quality system integration in the construction sector. Further Loushine et al. (2006) find three barriers to successful quality system implementation as shoddy implantation, the nature of the construction work and the industry itself.

The applied definition of project quality in this thesis is based on two components. Internal quality is the ability to perform or the input (the quality of management) according to required specifications, and the external output quality (the quality of performance) is the level of end-user satisfaction (Flynn et al. 1994; Fujimoto 1989; Fynes and De Burca 2005; Voss and Blackmon 1994). Failure costs are defined as the financial losses related with the production of a non-conforming product (Abdelsalam and Gad 2009; Cartin 1999).

1.1.4. REDUCED PROJECT SUCCESS OUTCOME

Success or failure of a construction project is normally determined by its ability to conform according to contract agreed budget, duration and level of specified quality (Hoffman et al. 2007). However, Zwikael and Sadeh (2007) and Shenhar and Dvir (2007) note projects mostly fail to achieve the agreed project requirements. Zwikael and Smyrk (2012) use the Sydney Opera House as example of a project which is considered as project failure in project management context, due it exceeded the construction duration from four to ten years, and literally blow the budget from AU$ seven million to AU$ 95 million (Jones 2006). Nevertheless, is the Sydney Opera House today listed at the UNESCO World Heritage Site and have become a symbol at the city Sydney and Australia (Zwikael and Smyrk 2012), and must hence be considered to be of great value and success for the project stakeholders. Whatever the Sydney Opera House would have become an equally success if the project had performed according to original agreed budget and duration is however not possible to tell.

The output and its potential success or failure of a project seems thus divided into a more complex circumstance than myopic conventional project performance related values such as cost, time and quality, also known as the “iron triangle” (Dvir and Lechler 2004). On the other hand, the PMBoK (2000) define a project as a temporary endeavor undertaken to create a unique product, service or result, and leave for that reason space for others outcome perspectives than the ordinary cost,

time, and quality perspectives. Liu and Walker (1998) divide successful project outcome into three categories: project goals, satisfaction of the claimant(s) and perception and awareness of different claimant(s), and further find the "iron triangle" elements too simplistic to evaluate the level of project success. Factors affecting the individual perception of project success and hereby indirect internal and external quality were self-efficacy, project complexity, commitment, expectancy, rewards, goals and environment (Liu and Walker 1998).

The applied definition of project success in this thesis is defined as a construction project that is completed according to contract agreed budget and deadline, and is executed in accordance with required specification (internal quality) and end-user satisfaction (external quality) (Long et al. 2004).

1.2. PREVIOUS WORK IN THE RESEARCH FIELD

1.2.1. PROJECT RISK ASSESSMENT AND MANAGEMENT

To reduce the frequency of construction projects cost and time escalations. The existing body of knowledge tends to focus at identifying and rank the critical success factors associated to cost and time by applying the relative importance index. Aibinu and Odeyinka (2006); Al-Kharashi and Skitmore (2009) and Kazaz et al. (2012) studied the schedule associated causes for delays and find financing of projects, lack of qualified and experienced personnel and design, and material changes as the greatest single factors effecting schedule delays. Looking into the cost related concept Iyer and Jha (2005) find poor human resource management and labor strike as the most affecting factor at project cost. However, Shane et al. (2009) identify 18 primary cost related causes and state that no definitive prioritized structure of the causes can be made, due to the cause effects is dependent of the project type. Finally,Kaliba et al. (2009); Koushki et al. (2005); Olawale and Sun (2010) all studied the time and cost related causes as interrelated. They find bad or inclement weather, contractor-related problems and design changes as the most cost affecting factors. In regards to the time concept delayed payments, changing orders and design changes were found furthermost affecting.

Zwikael and Globerson (2006) argue critical success factors are too general and do not support the project manager's decision making, and instead state identification of critical success processes is more beneficial to reduce critical increases. However, Doloi et al. (2012) extend this debate by arguing for the importance of identifying the level of relationship between the factors instead of analyzing one factor individual rank, and instead apply principal component analysis to do so. Haimes (2005) argues that risk analysis can be divided in two perspectives. Firstly, risk assessment (mostly a qualitative approach) involve the analysts to consider what can go wrong, likelihood that it go wrong, consequences, and the time domain of it. Secondly, risk management builds on the assessment process by mostly apply a quantitative approach which supports the analysts to consider what can be done, options available, associated trade-off of relevant costs, benefits and risk, and lastly the impacts of current management decisions on future options. Applying both the assessment and management perspective in the analysis

thus define total risk management as a systematic, statistically based holistic process (Haimes 2005).

The applied definition of a project risk in this thesis is defined as a measure of the probability and severity of adverse effects (Haimes 2005). The probability or likelihood is the chance the problematical event actually occur (Nicholas and Steyn 2012). The effect is the impact of the event if it appear (Nicholas and Steyn 2012).

1.2.2. INDUSTRIALIZED CONSTRUCTION PROCESSES

Industrialized construction processes and products have in the last century experienced an increased focus from the construction industry. Sacks and Partouche (2009) studied the Empire State Building (completed in 1931) by reconstructing the original scheduling and finding the applied production system categorized as a mass construction system. Further, Sacks and Partouche (2009) find the average construction rate for tall office and commercial buildings declining, due to increased project complexity and interconnected sub-systems in modern buildings. Johnsson and Meiling (2009) discovered that industrialized construction projects have a lower defect rate (higher level of product quality) than conventional onsite construction methods, but argue at the same time that systematic identification of defects and deviations in the process should have a larger focus, instead of solely correcting the product by "fire-fighting management" up to completion. The decision of applying off-site production or onsite construction methods is mostly based on cost related arguments, rather than value elements such as health and safety, sustainability, effects on management and process are of lower prioritization for project decision makers according to Blismas et al. (2006).

Thuesen and Hvam (2011) argue off-site manufacturing is having an increased focus from the construction industry, researchers and policymakers, and find reduced project cost of 30 % or more by apply off-site manufacturing. Clarke and Herrmann (2004) find the Danish construction industry use significant less labor intensity compared to England, Scotland and Germany to produce one square meter, due to an extensive use of prefabricated elements such as bathroom pods. Linner and Bock (2012) studied the Japanese prefabrication industry, due and extensive use and world leading expertise in the field of off-site construction, and find the services in the utilization phase highly prioritized, rather than only focusing at producing off-sites construction components. Similar results have been demonstrated by Barlow et al. (2003) that find the Japanese prefabrication industry different from the others, due to an implemented build-to-order technique by applying elements such as: standardization, prefabrication and effective supply chain management.

The applied definition of a product platform in this thesis is defined by Meyer and Lehnerd (1997) as a: "*set of subsystems and interfaces that form a common structure from which a stream of derivative products can be efficiently developed and produced"*. Nevertheless, the applied definition of mass customization in this thesis is defined by Tseng and Hu (2014) as: "*producing goods and services to meet individual customer´s needs with near mass production efficiency"*. Both definitions are applied since they are often applied in construction research literature by for example Thuesen and Hvam (2011).

1.2.3. PROJECT PLANNING AND COST SCHEDULING

According to Dvir et al. (2003) project planning and preparation do not guarantee a successful project outcome, but a total lack of it does on the other hand guarantee a project failure. Accurate planning of construction projects is therefore a cornerstone to ensure project delivery according to agreed schedule and budget (Chan 1996). Laufer (1990); Laufer and Tucker (1987) divide the project planning process into four components: what activity to be completed, how the activity should be completed, who should complete the activity and lastly when the activity should be completed. The PMBoK (2000) argue for four project phases: the initiation, planning, executing and closing processes. The initiation phase includes official approval and implementation into an existing organization of the upcoming project. Secondly, the planning phase defines the project scope to select the most efficient execution plan according to the project scope. Thirdly, estimated project resources such as labor, machinery, time and money are coordinated and monitored according to agreed project scope, deadline and budget. Lastly, in the closing phase the project is formally handed over to the stakeholder(s) and considered completed according to contract agreed time, cost, scope and specifications.

Galloway (2006) find that 67 % of the contractors apply the critical-path method to plan and monitoring the construction process. Lu and Li (2003) develop the critical-path method by apply a resource activity module into the existing method. However, Hegazy and Menesi (2010) argue the critical-path method has drawbacks since the level of planning often is to general, and instead proposes a critical path segment method where a more detailed planning level by decomposing the length of each activity into time segments separately is found more beneficial. To monitor projects schedule and cost performance Nicholas and Steyn (2012) demonstrate that by registering the earned value, planned value and actual cost of work performed during the project phases, schedule and cost performance indexes can be applied. Chan and Chan (2004) developed a model to predict the total construction duration by applying regression analysis, and find the model applicable in the construction industry by applying the scheduling performance index as benchmarking tool. Another scheduling approach for predicting and simulating the most effective project time and cost, is program evaluation review technic and Monte Carlo simulation. Barraza (2010) demonstrates that stochastic allocation techniques based at Monte Carlo simulation can give reasonable likelihood estimates for deciding the length of construction projects.

The applied definition of a project in this thesis is defined by Nicholas and Steyn (2012) by seven components: involving a single definable purpose and well-defined end-items or deliverables, unique, somewhat or largely unfamiliar, utilizing skills and talents from multiple professions and organizations, a temporary activity, something at stake, and lastly the process of working to achieve a goal. Nevertheless, the applied definition of project planning in this thesis is defined by Zwikael and Globerson (2004) (based on Meredith et al. (1995)) as: "*the establishment of formal plans to accomplish the project's goals*". Lastly, applied definition of cost scheduling in the thesis is defined by Nicholas and Steyn (2012) as: *"a realistic assessment based upon known facts about the work, required resources, constraints, and the environment, derived from estimating methods"*.

1.3. POTENTIAL SOLUTIONS IN THE RESEARCH FIELD

1.3.1. PROACTIVE PLANNING AND COST SCHEDULING

Project planning is often the first task to be carried out by the project manager (Zwikael and Globerson 2004). Hanna and Skiffington (2010) argue that preconstruction planning is an essential task to handle situations and risks before they affect the construction process. They further argue that it gives the contractor the ability to manage projects proactively rather than trouble shooting problems reactively as they arise in the process (Hanna and Skiffington 2010). Dvir et al. (2003) studied the relationship between the level of project planning and success and conclude that the effort to define project goals and deliverable requirements in the initial stage in collaboration with the customer or end-users is significantly vital. Significant positive correlations between defining project goals, functional and technical specifications with project success in the end-user perspectives were thus demonstrated by Dvir et al. (2003). However, Dvir and Lechler (2004) later find the positive effect of project planning overruled by the negative effect of project goal changes, and instead argue that project managers should invest more effort in capturing the "real" project requirements from the end-users to reduce the level of project goal changes. This contradictory result was based on the fact that construction projects often undergo changes, and as a consequence when completed no longer seem relevant for the end-users and stakeholders Dvir and Lechler (2004).

Gibson Jr et al. (2006) demonstrate, however, contrary to Dvir and Lechler (2004), a significant linear positive relationship between level of pre-planning and increased project performance of cost, duration and end-user satisfaction. Zwikael et al. (2014); Zwikael and Sadeh (2007) build bridge between the two contrary research results by demonstrating significantly improved schedule, budget, technical performance and end-user satisfaction by increased level of pre-planning in high risk projects, but do not find a significant improvement in low risk projects. The level of pre-planning should thus be adjusted according to the level of project complexity and risks associated with the general project process. To evaluate the quality level of project planning Zwikael and Globerson (2004) developed the Project Management Planning Quality index by measuring 17 organizational support products and 16 project know-how planning products. By apply the PMPQ index Zwikael and Globerson (2006) find the level of project planning highest in construction and engineering organizations and lowest in manufacturing related organizations. The high level of planning in the construction and engineering organizations further showed, according to Zwikael and Globerson (2006), that they were able to complete projects by half of the frequency of cost and time overruns, as compared to organizations in other industries.

The applied definition of pre-planning in this thesis is defined by Gibson Jr et al. (2006) as: *"the process encompassing all the tasks between project initiation and the beginning of detailed design"*. Aliases for pre-planning such as front-end loading, front-end planning, feasibility analysis, programming/schematic design and conceptual planning is according to Gibson and Gebken (2003) all synonymous for pre-planning. Nevertheless, the applied definition of preconstruction planning is

according to Hanna and Skiffington (2010) defined by the four project planning process components firstly defined by Laufer (1990); Laufer and Tucker (1987).

1.3.2. PROJECT COMMISSIONING

Project commissioning in the construction industry is according to Dasher et al. (2004) characterized as a concept that increases the probability for construction projects fulfilling the contract agreed stakeholder requirements. However, the concept was first applied by industrial engineers in the American navy to fine-tune processes and to test new developed equipment´s and vessels according to McFarlane (2013). Project commissioning is according to Tseng (2005) based on three parameters: firstly, it is a process orienteered concept, secondly, it is a process focus at internal and external quality, and finally a process which focus on project requirement performance. Both Kibert (2012); Pulaski et al. (2006) note the services related to project commissioning in the construction sector is increasing and so is the demand for it. This demand particularly is stimulated since the governments worldwide demand energy efficiency and performance of new, existing and refitted buildings. But also increased use of comfort systems such as heating, ventilation, air condition and mechanical systems from project stakeholder demand higher focus on these comfort systems (McFarlane 2014). Looking into the benefits of applying project commissioning, a reduced total utility cost, reduced maintain cost, repair and replacements and increased staff productivity are achievable (Wolpert and Bowman 2006).

To secure a successful project output McFarlane (2014) argue that project commissioning should be integrated into the project phases: planning, design, construction and post-occupancy stage. Enck (2010) supports this statement by demonstrating a relationship between project partners´ effort invested in defining end-goals and owner project requirements having an effect of how costly the project will become. The project stakeholders and end-users is for that matter of fact an key player within the process, and has therefore the responsibility to both prepare and continuously maintain the owner project requirements (McFarlane 2013). Nevertheless, Pulaski et al. (2006); Turner et al. (2012) extend these results by stating that the predesign stage of a construction project is significantly important for the owners ability to influence a project, since it is the least expensive project stage to adjust a project in. Project commissioning is divided into two different industry accepted approaches known as process commissioning and technical commissioning (McFarlane 2013). Process commissioning applies sub-sample tests pointed out by the commissioning authority to secure contract agreed specifications. Technical commissioning applies a full test of the functional performance and inspection to secure required specifications. However, final testing, adjustment and balancing of the heat, ventilation, air condition and mechanical systems are often, according to McFarlane (2013), not conducted due to contract agreed deadline pressure.

The applied definition of project commissioning in this thesis is defined according to ASHRAE (2005) as: *"a quality orientated process for achieving, verifying, and documenting that the performance of a buildings facilities, systems, and assemblies meets defined objectives and criteria"*.

1.4. RESEARCH OBJECTIVES IN THE RESEARCH FIELD

1.4.1. RESEARCH STRUCTURE AND OBJECTIVES

By looking at the existing state-of-art literature there clearly is a potential to study if proactive project pre-planning is a solution to the existing challenges of budget and duration escalations in the construction industry. The main research objective of this Ph.D. thesis is therefore to investigate:

If increased focus on project planning and cost scheduling before the construction stage stabilizes the construction process, and reduces time and cost increases?

In this thesis, the author firstly presents the research hypotheses applied in the conference and journal articles to be able to answer the main research objectives. Research methodology and methods applied in the thesis and each publication are then afterwards described and accounted for. The outcome of each research publication will be presented in the result section. Lastly, the research results will be discussed up against existing state-of-art literature to account for the research gap this Ph.D. thesis contributes to filling. Finally, concluding remarks and recommendations to further research will further be included in this section.

1.4.2. RESEARCH HYPOTHESES

Research hypothesis 1: How often are evaluations carried out? And which trade group focus most on evaluations? (Addressed in paper no. one).

Research hypothesis 2: What literature output exists associated to advantages and disadvantages of pre-planned construction projects? (Addressed in paper no. two).

Research hypothesis 3: What journal has published most relevant articles? How has the publication trends developed in the period of 2002 - 2012? And in what year was the greatest amount of new results published? (Addressed in paper no. three).

Research hypothesis 4: What selection and assignment criterion is mostly used in public construction tenders? How is different type of construction projects using selection and assignment criteria? And is there any significant difference between the use of selection and assignment criteria in public construction projects? (Addressed in paper no. four).

Research hypothesis 5: What selection and assignment criterion is mostly used in public construction counselling tenders? How is different type of construction counselling services using selection and assignment criteria? And is there any significant difference between the use of selection and assignment criteria in public construction counselling services? (Addressed in paper no. five).

Research hypothesis 6: How much attention does budget and schedule have in the initial project phases? And what factors affect budget and

schedule increases in publicly funded construction projects? (Addressed in paper no. six).

Research hypothesis 7: What factors have the most negative effect on time, cost, and quality? To test if a factor affects time, cost, and quality significantly different? And finally if a factor's effects are significantly different, to identify how the elements in the "iron triangle" are individually affected? (Addressed in paper no. seven).

Research hypothesis 8: What factors affect the tested agencies time, cost and quality significantly different from one another? And how significantly different are the tested agencies in terms of time, cost and quality? (Addressed in paper no. eight).

Research hypothesis 9: What underlying latent structures affect construction projects' schedule and budget performance? And to develop regression models to predict the impact of these structures on the level of errors or omissions in the completed construction work. (Addressed in paper no. nine).

Research hypothesis 10: How, from a projects manager's perspective, cost and time scheduling is conducted in the different project phases of publicly funded construction projects? And whether there are significant relationships and interactions between the critical factors affecting project time and cost negatively? (Addressed in paper no. ten).

Research hypothesis 11: How proactive planning and commissioning reduce cost, time overruns, and secure owner requirements in publicly funded construction projects? And what is the difference between pro- and reactive planning? (Addressed in paper no. eleven).

CHAPTER 2. RESEARCH DESIGN

Creating knowledge within business organizations is according to Arbnor and Bjerke (2008) an process which can be handled by either scientific methods and activities, and on the other hand consulting investigations. Nevertheless, for both scientific and consulting knowledge processes choosing and design a knowledge creative process is influenced by a combination of personal conviction, character of the problem, educative tradition, culture, scientific ideals, and social values (Arbnor and Bjerke 2008). The difference of knowledge created by scientific methods, compared to any other, is however that the chosen method and its results are presented for public and critical reviews by other creators of scientific knowledge (Arbnor and Bjerke 2008).

To account for the personal conviction in the dissertation and the chosen methodological approach, the framework by Arbnor and Bjerke (2008) is applied, see Figure 1. The strength of this framework is that it presupposes the ultimate presumptions and orientation of paradigm from the involved knowledge creator define the applied theory of science. The applied methodological approach is hence based on the theory of science shaped by the researcher´s personal conviction. The methodological approach is thus the basis for which operative paradigm, methods and procedures are applied to study in a specific area. Each element of the methodological framework will be accounted for in relation to this dissertation.

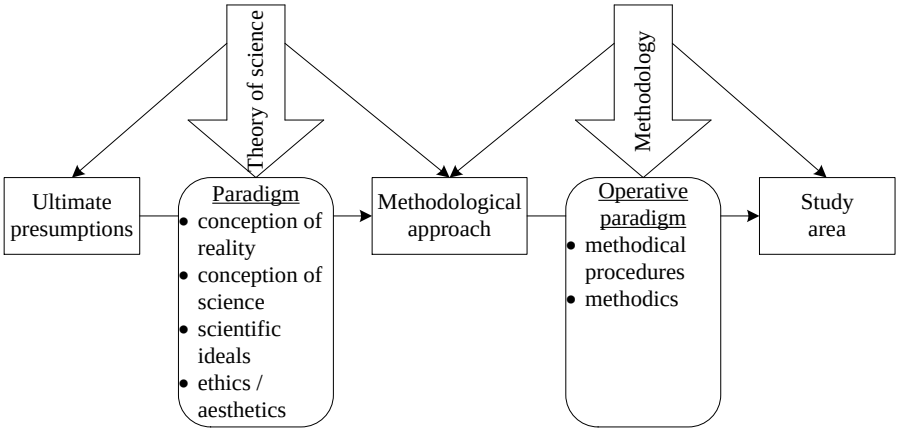

Figure 1: Methodological framework applied in this thesis, adapted from Arbnor and Bjerke (2008).

2.1. SCIENTIFIC PARADIGM

Every individual has different perceptions of the world we live in. However, trying to explain and understand this world demands according to Arbnor and Bjerke (2008) the creator of knowledge answering five questions with solid philosophical arguments and considerations: 1) what are the ultimate presumptions held by the creator of knowledge?, 2) what kinds of questions are asked?, 3) what kinds of

concepts are used to formulate these questions?, 4) what kinds of methods are used to explain and understand the world?, and lastly 5) what kinds of answers or solutions are given to the questions? Ferrier (1856) describes the complexity of the perception of the world and knowledge very well: *"we are scarcely in a position to say what is, unless we have at least attempted to know what is; and we are certainly not in a position to know what is, until we have thoroughly examined and resolved the question - What is the meaning of know? What is knowledge? What is knowing and known?".*

Ultimate presumptions are characterized by a paradigm containing a specific perception of the world often applied within a specific field of science and its researchers as introduced by Kuhn (1996). Nevertheless, over time new paradigms are shaped replacing older paradigms, as often seen in natural sciences. In social sciences however, new paradigms often live along with the existing paradigms (Arbnor and Bjerke 2008).

Classification and existence of the paradigms is thus also continuously debated in the different research fields. Fellows and Liu (2008) describe two paradigms (positivism and interpretivism) similar considerations are presented by Coughlan and Coghlan (2002); Gummesson (2000), arguing for the existence of positivism and hermeneutic paradigms. Arbnor and Bjerke (2008) operate based on two paradigms (objectivist-rationalistic and subjectivist-relativistic) but divide the span between the two paradigms into six sub-category paradigms. Similar sub-division is demonstrated by Halfpenny (1982), finding 12 sub-variations of positivism. Guba (1990) however, claim the existence of four paradigms (positivism, post positivism, critical theory and lastly constructivism). Similar classification of paradigms are presented by Creswell et al. (2003) (positivism, post positivism, interpretivism, participatory/advocacy and pragmatism).

2.1.1. CONCEPTION OF REALITY

Arbnor and Bjerke (2008) argue for the existence of six conceptions of reality, see Figure 2. Lower numbers observe the world and reality as objective and rational, relations of philosophy are decreased, explanatory knowledge is considered central, and general results and empirical evidence are sought (Arbnor and Bjerke 2008). Higher numbers however, consider the reality as subjective and relative, relations of philosophy are increased, understanding knowledge is considered central, and specific and concrete results are sought (Arbnor and Bjerke 2008).

In this thesis the conception of reality has been that reality (both external and internal) should be seen as factual and unspoiled by biased subjective impressions, similar to Emile Durkheim (Arbnor and Bjerke 2008). However, the author is also of that impression, similar to Immanuel Kant, that we as human beings cannot obtain and comprehend objective reality, since humans cultivate this reality. Human experience and reality can thus only appear in cultivated form (Arbnor and Bjerke 2008). Alfred Schutz´s perception, that understanding how subjective realities occur thus seems central for further progress in social science. This perception from Alfred Schutz thus also seems complementary to the two perceptions from Emile Durkheim and Immanuel Kant.

The author does on basis of the three accounted perceptions of reality argue that in this dissertation the ultimate reality presumptions is a combination of: reality as concrete and conformable to law from a structure independent of the observer, reality as a concrete determining process, and lastly reality as mutually dependent fields of information, see Figure 2 (Arbnor and Bjerke 2008).

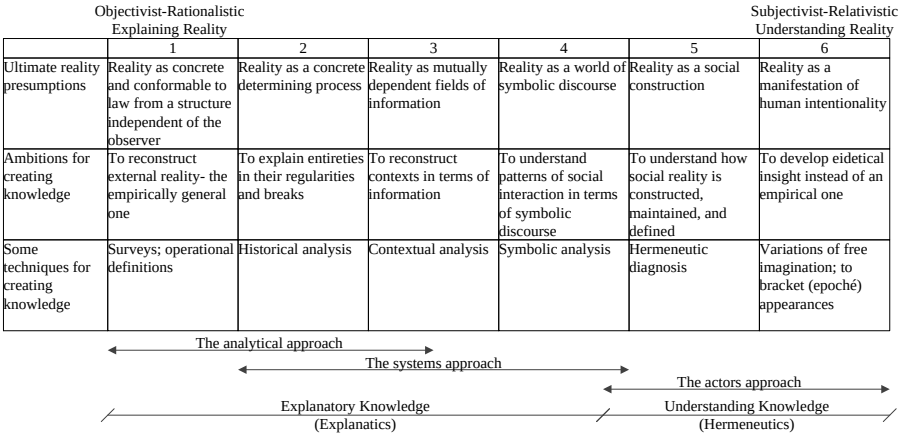

Figure 2: Classification of the six sub-categorizes paradigms with the methodological approaches, adapted from (Arbnor and Bjerke 2008).

2.1.2. CONCEPTION OF SCIENCE

The progress of science and research is an ongoing cycle which can so far be divided into five cycles in the history of the development of science and research (Jamison et al. 2011). The exact beginning of research at institutional level starts approximately in the year 1660 with the establishment of the Gresham College in London, which six years later (the year of 1666) publish the first scientific journal (Jamison et al. 2011). The period up until approximately the year 1830 (the end of the first cycle) was mainly shaped by the Industrial Revolution and scientifically focus on a period of mechanization (Lilley 1970). The first cycle of research was furthermore the Age of Enlightenment and romanticism as cultural movements.

Second cycle (between year 1830 to 1880 approximately) was scientifically dominated by developing technologies for socialization. The second cycle was also known as the Age of Capital (Jamison et al. 2011). This shifting research focus to socialism and populism were stimulated by the "machine-storming" in the year of 1810 in England. Workers and craftsmen sabotaged the factory machines due to layoff and starvation. A balance between the school of mechanization as Emile Durkheim represent, and opposed by Ferdinand Tönnies representing the more organic society orienteered school were needed (Jamison et al. 2011).

The Age of Empire (between year 1880 to 1930 approximately) was the third cycle (Jamison et al. 2011). This cycle represents a time where research focused on developing technologies of modernization. Furthermore, this cycle incorporated technology and science into industrial oriented research and development companies such as General Electric, General Motors and DuPont (Jamison et al.

2011). With the economic growth, large-scale industrialization was again significant. Henry Ford was one of the pioneers of the time with the mass production and assembly lines to mass produce automobiles (Jamison et al. 2011). The cultural movements was focused on modernism and anticolonialism (Jamison et al. 2011).

Looking into the fourth cycle or the Age of Big Science (1930 to 1980 approximately), this was significantly dominated by military related research such as atomic energy and bombs, petrochemicals, and computers (Jamison et al. 2011). This research shift was motivated by the first and second world wars, the Korea and Vietnam wars and finally the race between the United States and USSR during the cold war. Nevertheless, this cycle can according to Jamison et al. (2011) be dived into four sub-periods of main orientations: industrial (before the WWII), atomic (1940-1950), societal (1960-1970), and commercial (1980). Civil rights and protest against the wars and its research, environmentalism, feminism and postmodernism characterized the social and cultural movements in society (Jamison et al. 2011).

The fifth cycle or the Age of Information starting in 1980 focusing particularly at the research field's information technology, biotechnology and nanotechnology. Jamison et al. (2011) note that the three research fields are different from others as they are supply-driven rather than demand-driven in their societal need. Furthermore, it is argued that the collaboration between industry and universities has become market oriented with an entrepreneurial norm for collaboration (Jamison et al. 2011). Looking into the social and cultural movement Jamison et al. (2011) argue that ecological and global justice, open source, and lastly identity politics are in focus.

Understand how the progress of science and research historically have developed and shaped the culture, seems thus significant to comprehend the underlying causes and reasons for the research paradigms existing.

2.1.3. SCIENTIFIC IDEALS

The new knowledge presented in this dissertation is based on research hypotheses that will be evaluated by applying well-established and acknowledged techniques, mostly applied from the natural science. The outcome of the project will provide a more precise picture of publicly funded construction projects as they operate in reality. The more causes affecting an either positive or negative response the research project discover, the more precise and closer to reality the explanations will be. From an operational research perspective this research will extend the understanding of how project practice and logic operate, but does not provide answers for how operationally to take actions to solve them (Ormerod 2009). Auguste Comte: *"Science leads to predictions; predictions lead to action"* (Arbnor and Bjerke 2008).

2.1.4. ETHICS AND AESTHETICS

According to Børsen (2013) scientists, engineers, scholars and other creators of knowledge all have a responsibility to reflect on their knowledge creating process and outcome up against social responsibilities to avoid and consider ethical dilemmas. Børsen (2012) defines an ethical dilemma as when: *"a conflict of ethical*

norms; several ethical value systems is in collision". However, Rotblat (1985) notes the concept of morality and considerations is often overruled when military actions or campaigns start, and further argue that we as human beings must eliminating all kinds of war, due to its disintegrate the morality and the whole civilization. Rackham (1934) describe ethical judgement as divided into five intellectual variations: Epistéme, Techné, Phronesis, Nous and Sophia. Børsen (2012) notes that the ethical judgement is based on intellectual perspective Phronesis, and further argues no universal and definitive solution exists to an ethical dilemma.

To secure ethics and aesthetics in the research several precautionary actions have been taken. Looking into the ethical perspective of the study, the categorical principle was applied by treating involved persons not only as a mean or study aim. The precautionary principle was thus applied so that if the research potentially had any reasonable damage or effects on the participants or the collaborative organizations, no research activities were started. Further, to secure highest available standards. The ethical research standards of the Danish Social Science Research Council were followed and the Danish Data Protection Agency was involved during the research process.

2.1.5. CRITICAL RATIONALISM

A number of research projects within this research area apply and embrace a relevant scientific paradigm which is not described by Arbnor and Bjerke (2008). The paradigm critical rationalism first introduced by Karl Popper in 1934 in his book *The Logic of Scientific Discovery*, later translated to English in 1959 (Caldwell 1991) is considered highly relevant to apply within this research project. Karl Popper was particularly inspired by Albert Einstein´s way of arguing for his theory of relativity in 1919 (Heyt 1999). According to McFarlane (1990) Albert Einstein firstly viewed his theory as a step forward but considered it replaced by a improved theory in the future. Secondly, Albert Einstein considered his theory disproved if it failed experimental tests. The power of falsifying a theory occurred further to Karl Popper during his exile in New Zealand in the late 1930s (Ulrich 2006). Before his stay in Christchurch he had taken for granted that all swans were white, but experienced to his surprise that some swans in fact were black (Ulrich 2006).

The amount of observations seems therefore of no relevance to confirm a theory, but a single counter observation can falsify the theory and replace the older one (Schroeder-Heister 2001). This swift from the inductivism principle of verifiability as the Vienna Circle represents, to the deductivism principle of falsifiability as Karl Poppers critical rationalism represents however is still subject to debate between the two (Faran and Wijnhoven 2012; Ulrich 2006). Nevertheless, scholars within diverse research fields such as social work and health, law, accounting, education and learning and engineering have considered critical rationalism of relevance when conducting operational research (Ormerod 2014). According to Staples (2014); Staples (2015) critical rationalism and the engineering disciplines are particularly applicable in the perspective of both engineering ontology and methodology.

The concept of critical rationalism is according to Faran and Wijnhoven (2012) based at four pillars: the primacy of deductive logic, the elimination of psychologism, the quest for active criticism, and lastly the problem-solving orientation. The distinguishing characteristic of science and pseudo-science according to Karl Popper is that universal theories can never be verified with any probability, but can only be falsified with a more comprehensive theory replacing another (Ormerod 2009). However, McFarlane (1990) and Dryzek (1987) both note the link between critical rationalism and libertarianism. McFarlane (1990) argue both science and market knowledge increase by trial and errors, to get closer to the reality or the customers. Concerning faith, beliefs and others irrationally aspects Watkins (1969) argue the rationalist should try to be as rational as possible and be open for to criticism, but due acknowledge this part of the human behavior.

Critical rationalism thus is a research paradigm which both explicitly and implicitly is considered highly relevant to apply in this research project. The purpose for this project therefore is to falsify existing theories related to the positive relationship between efforts applied in pre-project planning activities and the following level of project success at completion stage and to replace the existing theory by a new and more comprehensive one.

2.2. RESEARCH METHODOLOGY

The applied framework developed by Arbnor and Bjerke (2008) argue the ultimate presumptions and paradigm from the creator of knowledge cumulative shape the applied methodological approach. Arbnor and Bjerke (2008) divide the different approaches into three methodologies: the analytical approach, the systems approach, and the actor's approach. The methodological approach chosen in this thesis is thus an outcome of the author's views of the world see Figure 2 with the six sub-paradigms compared to the three methodological approaches.

The analytical approach is according to Arbnor and Bjerke (2008) the oldest of the three, but still today often applied in public investigations. The approach is considered related to the tradition of Western theory, based on its association to the classic analytical philosophy. The knowledge outcome from applying this approach is thus independent of the observer, by only applying theories or parts of theories, which either can be verified or falsified. This independent oriented outcome is based on the summative character that distinguishes this approach, from the other approaches, by seeing reality as the whole sum of its parts (Arbnor and Bjerke 2008).

The systems approach was introduced to business research in the 1950s, as an alternative to the perception of reality the analytical approach represents (Arbnor and Bjerke 2008). It quickly became the most applied approach in both business theory and practice, due to its more holistic oriented perception of problems. The knowledge outcome by applying this approach depends according to Arbnor and Bjerke (2008) on the general systems where individual parts are explained by looking into the characteristics of the whole. The largest differences between the analytical and systems approaches are nevertheless the perception of reality. The systems approach perceive reality as the whole differing from the sum of its parts,

meaning that individual relations also are considered significant (Arbnor and Bjerke 2008).

The actor´s approach started as an independent approach in the end of the 1960s, assisted by research conducted in organizational sociology (Arbnor and Bjerke 2008). The output of knowledge by applying this approach is highly dependent on the involved actors and individual subjective provinces of meaning, and mostly related to research conducted in social business structures. This approach is therefore different from the analytical and systems approach by seeking social understanding as a whole. Reality in this approach is perceived by applying social construction to create different levels of structures and meaning of the whole (Arbnor and Bjerke 2008).

In the context of this thesis, the analytical and systems approach are applied. The analytical approach points towards the research paradigm one and two see Figure 2. Applying the analytical approach implies explaining the system parts independently of the whole system. Contrary to this, the systems approach is used to support the research paradigm two and three see Figure 2. Using the systems approach however, implies explaining the system of proactive planning and cost scheduling with the interrelationship between the sub-parts of the system as a whole.

2.3. SCIENTIFIC OPERATIVE PARADIGM

2.3.1. METHODICAL PROCEDURES

This dissertation applies, according to Arbnor and Bjerke (2008) definitions, a combination of analytical approach and systems approach to explain system parts independently, and its interrelationship between sub-parts of the system as a whole. Applying Jørgensen (2000) methodical procedure, which is commonly used to structure either research projects and development projects within businesses, is thus relevant, see Figure 3. According to Jørgensen (2000) the methodical procedures is structured in two central system concepts: analysis and synthesis. The analysis is defined by Jørgensen (2000) as: *"Analysis (of an existing system) is 1) to investigate properties of the system and 2) to divide the system into system components and system structure"*. Whereas the synthesis defined by Jørgensen (2000) as: *"Synthesis (of a new system) is 1) to create the system by relating existing systems to each other by a structure and 2) to add properties to the system"*.

According to Jørgensen (2000) the two central system operations can be combined and sequenced in several combinations, but Jørgensen (2000) argues that a problem solving and a design sequence is the most applied research operation. A problem solving activity will initially be based on an identified or observed problem, followed by an analysis of the problem. The conducted analysis of the problem will thus be used to state a diagnosis. A stated diagnosis is followed by a synthesis, which finally will produce a potential solution to the stated problem. A design activity however, starts by defining a base used to conduct the synthesis. The synthesis activity creates the innovation which is then analyzed to create the specified outcome of innovation. Lastly, Jørgensen (2000) argues that the two

elementary operations and their sequences can be embedded in each other. The combination of each of the two elementary operations is illustrated in Figure 3 and shows the general methodical structure used in the research project.

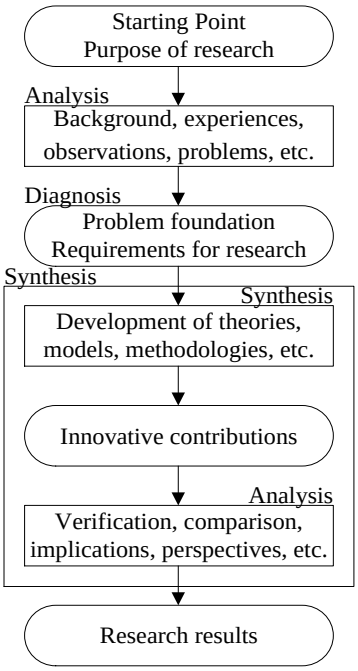

Figure 3: Methodical procedures commonly used structure of research and development projects, adapted from (Jørgensen 2000).

Considering that the research paradigm critical rationalism is applied, a developed theory cannot be finally confirmed or verified in this dissertation as proposed in Figure 3. The final verification activities should therefore instead attempt to falsify and stress the established theory and results to validate the study and to locate limitations of the theory and its results.

2.3.2. METHODICS

Applied research methodics have been widely selected according to the methodical procedure at Figure 3. Research activities in the beginning of the research project literature review, trend analysis, and pilot questionnaire were conducted to establish the research purpose (see paper no. one, two and three). Interviews and document analysis of tender cases of both construction projects and construction counseling services were then conducted to establish a research background, experiences, and to state the problems more specific (see paper no. four, five, and six). In the problem foundation phase a questionnaire was used as a basis for defining constructs (see paper no. seven and eight). Based on the questionnaire, theories and models of the reality were developed in the synthesis phase (see paper no. nine). To contribute with new innovation a multiple method was applied where data from the

interviews and questionnaire were mixed (see paper no. ten). Lastly, in the "verification" phase a case study was conducted by applying observations, interviews, questionnaire, and simulation (see paper no. eleven).

2.3.3. RESEARCH LIMITATIONS

This Ph.D. dissertation has been limited to study Danish state funded construction projects with a total project budget sum above the EU tendering threshold value for building and construction sector projects[1]. This limitation has been applied since state funded construction projects is considered complex, technical advanced, has complicated decision-making processes, and has focus of applying new technologies in both product and process perspective to streamline their projects (Smith and Stupak 1994). Implementation of the results and recommendations from the dissertation will thus be directly applicable to state funded construction projects, but will also be applicable to less complicated construction projects in Denmark and similar countries. The reader is recommended to carefully consider the limitations of the results and recommendations if used outside the described research area.

[1] 38,624,809.00 DKK exclusive of VAT 2014 - 2015.

CHAPTER 3. RESULTS OF RESEARCH

To demonstrate the Ph.D. project´s academic contribution in proactive planning and cost scheduling to reduce critical increases associated to publicly funded construction projects, this chapter accounts for the scientific contribution for each peer reviewed conference or journal paper produced throughout this project (see Appended Papers). The papers are organized in chronological order according to the general process and as a result give an interpretation of the research progress and its development. Each paper uncovers a subarea of the research project and thus cumulatively answer the main research question. In the following section each paper is presented by firstly accounting for the sub-question(s) and secondly, demonstrating the academic contribution to the research society.

3.1. PAPER ONE – FOCUS AT PROJECT EVALUATION

Larsen, J.K., Ussing, L.F., and Brunoe, T.D., (2013): Construction Projects Focus on Evaluation and its Benefits by Pre-planning, 11th International Post Graduate Research Conference.

The aim of this paper is to answer the following two questions:

How often are evaluations carried out? And which trade group focus most on evaluations?

- 34.9 % independently of the trade groups indicate project evaluation after completion "sometimes" (27.4 %) or "frequently" (7.5 %) is organized. However, 64.5 % of the asked respondents independently of the trade groups indicate evaluation "rarely" (32.2 %) or "never" (32.3 %) is organized. Finally, .5 % indicates they don't know.
- The trade group "architect" (2.34) indicates to have most focus on both internal and external project evaluation after completion. Trade groups such as "engineers" (2.08), "contractors" (2.07) and "client design advisors" (2.07) indicate to have a medium focus. Finally, "owners / developers" (1.99) indicate the lowest focus at evaluation.
- Internal evaluation in the single trade groups is found to receive higher focus than external evaluation with diverse project partners represented. Feedback from evaluation sessions regardless of type and trade groups indicates further to have the lowest focus. Systematic transfer of project experience and learning to the single firms is thus not found existing.

3.2. PAPER TWO – PROS AND CONS OF PRE-PLANNING

Larsen, J.K., Ussing, L.F., and Brunoe, T.D., (2013): Literature Review of Advantages and Disadvantages of Pre-planned Construction Projects, 13th PhD Conference on Research in Business Economics and Management.

The aim of this paper is to answer the following question:

What literature output exists associated to advantages and disadvantages of pre-planned construction projects?

- Cost and schedule increases are found to be an international challenge registered on five continents, which has not decreased in the last 70 years in the construction industry. The project manager´s ability to manage scope changes are thus discovered as significant to secure project success.
- The level of pre-planning effort has been found linear positive associated to construction projects ability to perform according to contract agreed budget, improve quality level, and reduce project duration and risk in the process. However, diverse planning objectives between the project organizational levels are found problematic.
- Industrialized pre-assembled construction systems are found to stimulate a higher effort at pre-planning to reduce "firefighting management" in the design and construction stages.

3.3. PAPER THREE – TRENDS AND RESEARCH DIRECTIONS

Larsen, J.K., Ussing, L.F., and Brunoe, T.D., (2013): Trend-Analysis and Research Direction in Construction Management Literature, 11th International Conference on Construction and Real Estate Management.

The aim of this paper is to answer the following three questions:

What journal has published most relevant articles? How has the publication trends developed in the period of 2002 - 2012? And in what year was the greatest amount of new results published?

- The Journal of Construction Engineering and Management from the American Society of Civil Engineers was found to publish the most relevant articles. Additionally, the second most relevant journal was found to be the Journal of Management in Engineering from same publisher. In total the two journals account for 54.1 % of the papers.
- The average trend of the yearly publication rate was a slowly linear increase. Nevertheless, the publication years 2005 (1.6 %) and 2006 (14.8 %) were the two years that demonstrated the greatest decline and increase compared to the average trend.
- The year 2006 was found to be the one where the largest amount of new significant results were published (45) and in total 69 outlets. Furthermore, the total number of outlets in the period 2002 to 2012 was 312. 192 of these outlets were registered as significant new to the research area.

3.4. PAPER FOUR – ANALYSIS OF CONSTRUCTION TENDERS

Larsen, J.K., Ussing, L.F., and Brunoe, T.D., (2013): An Analysis of Project Selection and Assignment Criteria of Danish Tenders in Europe, International Journal of Construction Supply Chain Management, Vol. 3, No. 2, pp 16 – 26.

The aim of this paper is to answer the following three questions:

What selection and assignment criterion is mostly used in public construction tenders? How is different type of construction projects using selection and assignment criteria? And is there any significant difference between the use of selection and assignment criteria in public construction projects?

- Invited tender with a pre-qualification process is the most applied selection criterion (80.9 % of the cases). The most applied assignment criteria is lowest price (75.2 % of the cases).
- Invited tender and lowest price is the most applied selection and assignment criteria in restoration, maintenance, and new construction projects. 69.8 % of the studied cases regardless of project type applied this tender combination.
- The use of invited tender was significantly more applied as selection criteria than open procedure tender in both project types. The use of lowest price as assignment criteria was non-significant more applied than most economically advantageous offer in both project types. Finally, the use of invited tender and lowest price was found non-significant from other tested tender combinations regardless of project type.

3.5. PAPER FIVE – ANALYSIS OF COUNSELLING TENDERS

Larsen, J.K., Ussing, L.F., and Brunoe, T.D., (2014): Danish Public Construction Counselling Selection and Assignment Criteria in European Tendering, 7th World Conference on Mass Customization, Personalization, and Co-Creation.

The aim of this paper is to answer the following three questions:

What selection and assignment criterion is mostly used in public construction counselling tenders? How is different type of construction counselling services using selection and assignment criteria? And is there any significant difference between the use of selection and assignment criteria in public construction counselling services?

- Invited tender with a pre-qualification process is the most applied selection criterion (86.5 % of the cases). The most applied assignment criteria is most economically advantageous offer (73.0 % of the cases).
- Invited tender and most economically advantageous offer is the most applied selection and assignment criteria in counselling services of new construction projects. 57.1 % of the studied cases regardless of project counselling type applied this tender combination. Counselling services of restoration and maintenance projects applied mostly invited tender and lowest price as selection and assignment criteria. 35.7 % of the cases regardless of project counselling type applied this tender combination.
- The use of invited tender was non-significantly more applied as selection criteria than open procedure tender in both project counselling types. The use of the assignment criteria most economically advantageous offer and

lowest price was found non-significant different applied of the two project counselling types. Finally, the use of invited tender and most economically advantageous offer was found non-significant from other tested tender combinations regardless of project type.

3.6. PAPER SIX – PLANNING AND BUDGETING IN PUBLIC PROJECTS

Larsen, J.K., Ussing, L.F., Brunoe, T.D., and Lindhard, S.M., (2015): The Project Management Process of Planning and Budgeting in Public Construction Projects, International Journal of Information Technology Project Management, Vol. 6, No. 4, pp 20 – 33.

The aim of this paper is to answer the following two questions:

How much attention does budget and schedule have in the initial project phases? And what factors affect budget and schedule increases in publicly funded construction projects?

- Early decision-making and optimistic expectations regarding budget and deadline performance combined with lack of project objective and end-user requirements are found in the initiation project phase. Project reductions were thus consequently applied to fit the intended project according to contract budget. This planning approach further stimulates a push effect so that the time pressure is forwarded to the following project tasks or phases, which are then pushed up against final contract deadline.
- 20 causes for project budget and deadline overruns were identified. Most of these (16 of the 20 causes) were related to internal project complications within the project organization and were found to have the largest effect. The externally related causes (4 of the 20 causes) were found to be project conditions or circumstances, of which the project organization had no control.

3.7. PAPER SEVEN – FACTORS AFFECTING PROJECTS PROCESSES

Larsen, J.K., Shen, G.Q., Lindhard, S.M., and Brunoe, T.D., (2015): Factors Affecting Schedule Delay, Cost Overrun, and Quality Level in Public Construction Projects, Journal of Management in Engineering, In Press.

The aim of this paper is to answer the following three questions:

What factors have the most negative effect on time, cost, and quality? To test if a factor affects time, cost, and quality significantly different? And finally if a factor's effects are significantly different, to identify how the elements in the "iron triangle" are individually affected?

- The main cause of project delay was identified as unsettled or lack of project funding. The factor with the greatest effect on project budget was errors or omission in consultant material. Finally, errors or omission in construction work was found to have the greatest negative effect on quality.

- 17 out of 26 of the tested factors affecting project delay, cost, and quality were found to affect significantly different. Nine factors were found to affect time, cost and quality non-significantly different. The impact of particular human project management related factors was found non-significantly different affecting.
- 33 of 51 of the following post-hoc tests were found to be significantly different in the combinations of time, cost, and quality. 10 out of 18 non-significant tests were between time and cost, 5 between quality and time, and 3 between quality and cost. All 51 post-hoc tests were found to be positively correlated.

3.8. PAPER EIGHT – FACTORS AFFECTING PUBLIC AGENCIES

Larsen, J.K., Brunoe, T.D., and Lindhard, S.M., (2015): Analyzing Factors Affecting Time, Cost and Quality between Diverse Public Construction Agencies, 13th International Conference on Construction and Real Estate Management.

The aim of this paper is to answer the following two questions:

What factors affect the tested agencies time, cost and quality significantly different from one another? And how significantly different are the tested agencies in terms of time, cost and quality?

- At the time perspective five (lack of requirement specifications in tender documents, slow user decision making, inexperienced or newly qualified construction supervisors, lack of identification of needs, and late user changes affecting the project or function) of 26 factors were found significantly different. Four (state of market conditions, slow user decision making, lack of identification of needs, and late user changes affecting the project or function) of 26 cost related factors were found significantly different between the agencies. Regarding the quality four factors (state of market conditions, lack of requirement specifications in tender documents, inexperienced or newly qualified construction supervisors, and lack of identification of needs) were found significantly different from one another.
- Four post-hoc test differences were found between agency A^1 and A^2, and one among agency A^2 and A^3 in the time related analysis. Regarding the cost perspective all four post-hoc differences were found between A^1 and A^2. The quality related post-hoc analysis three test differences were found between agency A^1 and A^2, and one among agency A^2 and A^3.

3.9. PAPER NINE – ANALYZING CRITICAL FACTORS IN PROJECTS

Larsen, J.K., Brunoe, T.D., and Lindhard, S.M., (2015): Analyzing Factors Affecting Cost Overrun, Schedule Delay and Quality Level in Public Construction Projects, Journal of Construction Engineering and Management, In Review.

The aim of this paper is to answer the following two objectives:

What underlying latent structures affect construction projects' schedule and budget performance? And to develop regression models to predict the impact of these structures on the level of errors or omissions in construction work.

- The underlying latent structures affecting construction projects schedule performance were identified as: A lack of quality control (47.3 %), project preparation (12.1 %), user management (8.2 %) and project management (7.5 %). The four components were in total explaining 75.1 % of the statistical variance. Regarding, the underlying structures affecting the budget performance were identified by a lack of quality control (53.5 %), project management (10.9 %) and project preparation (9.3 %). The three components were in total explaining 73.7 % of the statistic variance.
- The regression model for errors or omissions in construction work´s effect at project schedule = 1.545 + (.397Conflicts and disputes between project partners) + (.200Inexperienced or newly qualified construction supervisors). The regression model for errors or omissions in construction work´s effect at project budget = -.599 + (.792Errors or omissions in the consultant material) + (.267Complexity or volume of the project).

3.10. PAPER TEN – SCHEDULING BY NATIONAL GATE MODELING

Larsen, J.K., Brunoe, T.D., and Lindhard, S.M., (2015): Project Management and Scheduling trough National Project Management Phases in Government Construction Agencies, International Journal of Information Technology Project Management, Submitted for Review.

The aim of this paper is to answer the following two questions:

How, from a projects manager's perspective, cost and time scheduling is conducted in the different project phases of publicly funded construction projects? And whether there are significant relationships and interactions between the critical factors affecting project time and cost negatively?

- Identified project complications in the execution stage were found closely associated to the lack of project requirements and design with too optimistic project deadline and budget performance expectations from the initial project stages. A relationship between the presence of experienced design consultants and the achievement of project success throughout the project phases was thus found particular vital.
- Lack of project construction management skills seems further critical taking into account that all tested relationships between critical time and cost courses were found positive correlated. This implies not only that each factor has a negative effect on project time and cost, but also where these factors have a positive correlation with each other that additionally increases the negative factor impact at a project´s final deadline and budget.

3.11. PAPER ELEVEN – ENHANCED PROJECT PERFORMANCE

Larsen, J.K., Brunoe, T.D., and Lindhard, S.M., (2015): The Relationship between Preplanning, Commissioning and Enhanced Project Performance: A Case Study of Denmark, Journal of Construction Engineering and Management, In Review.

The aim of this paper is to answer the following two questions:

How proactive planning and commissioning reduce cost, time overruns, and secure owner requirements in publicly funded construction projects? And what is the difference between pro- and reactive planning?

- Proactive pre-planning and commissioning both reduce the probability of budget and time overruns, secures a higher level of owner and technical requirements fulfillment. By applying diverse competences and resources as early as possible in the project planning process as a team, high focus on owner and technical requirements, reduce rework and inefficient in the construction process and finally define a project vision and success parameters all together were find to secure a higher project success rate.
- The difference between pro- and reactive project planning is not the level of project success when completed but find in the general project process upon project complications that makes the significant difference to secure contract agreed requirements.

CHAPTER 4. DISCUSSION AND CONCLUSION

4.1. DISCUSSION OF RESEARCH OBJECTIVE

The research objective of this Ph.D. dissertation was to study: *If increased focus on project planning and cost scheduling before the construction stage stabilizes the construction process and reduces time and cost increases?* The theory that a positive correlation between effort applied in pre-project planning activities and the following level of project success exists is not new. Nevertheless, there have been contradicting findings in literature on whether the initial project phases actually do make a significant contribution to the level of project success when completed. The objective of this dissertation is however not to demonstrate the existing of the theory similar to Gibson Jr et al. (2006) or Dvir and Lechler (2004) with contradictory point of view. The objective is instead to falsify and stress the conducted results and theory to find potential limitations, where it falls to pieces.

This research finds the level of effort applied to project planning and scheduling activities in the initial phases of construction projects particularly vital to reduce the probability for schedule and budget overruns. But at the same time also secure a higher level of both contract required specifications (internal quality) and end-user satisfaction (external quality). Investing more effort in the initial project phases thus seems highly significant to secure project success after completion. Nevertheless, it was also uncovered that the largest difference between applying either a reactive or a proactive project planning approach is not the level of project success when completed. But it is the project manager and the organizations ability to handle unforeseen obstacles that makes the difference between success and failure. Pre-planning must thus be considered as a process-oriented management approach, which increases the probability of securing contract agreed duration, budget, and quality, not vice versa.

Contradictory results related to the studied theory are applied to falsify and test the results produced by this research. Dvir and Lechler (2004) demonstrate that the total positive effect of project planning is overruled by the total negative effect from project goal changes. Adjusting goal and plan changes are found to have a total larger effect on project success than the quality of planning. It thus seems that even though project planning is important it is not able to compensate for project changes trough the project phases (Dvir and Lechler 2004). Lastly, Dvir and Lechler (2004) argue more effort should be applied to specify the "real" end-user project requirements as a way to reduce the amount of project goal changes. Zwikael et al. (2014); Zwikael and Sadeh (2007) further demonstrated that increased effort in pre-project planning did not have a significant improvement at project schedule, budget, technical performance, and end-user satisfaction in low risk projects. However, they did also demonstrate a significant improvement at all four perspectives in high risk projects. Zwikael and Sadeh (2007) conclude, that the importance of pre-planning is highly dependent on the amount of risk and the success parameters that have been targeted.

The theory of pre-project planning and its effect on project success upon completion has to be considered according to the empirical conditions. The theory

clearly is falsified in projects, which have either low risk or a low complex nature. Applying pre-planning activities in simple construction projects will thus not make a significant improvement on project duration, budget and quality. However, it has not been possible to falsify the theory in projects which either have high risk or high complex nature. All attempts to falsify the theory in high risk and complex projects have so far failed in both existing literature and in this research. Empirical evidence falsifying the existence of the theory in high complex and risk projects must thus so far be considered non-existent.

The level of effort invested in pre-project planning activities thus must be considered and adjusted in scale individual in relation to the level of project complexity and its amount of risk.

4.2. CONCLUDING REMARKS

It is believed that the findings of this Ph.D. dissertation have contributed with extending and supporting the research area related to the theory of proactive pre-planning in the construction sector.

Each publication in this research represents a different perspective associated with the research objective. The papers can therefore be either read as individual results or in relation to the other papers. All published papers have undergone international peer review either before conference or journal publication. It therefore is the author´s persuasion that the research objective has been researched by scientific correctness and according to the research delimitation. The recommendation of this Ph.D. dissertation therefore is that an increased focus on proactive pre-planning activities in high risk or complex construction projects, benefit a construction project performance of cost, time and quality significantly by applying the principles of proactive pre-planning.

Nevertheless, it is acknowledged that further research in this theory is required before implementing a framework or concept into the construction sector. Particularly, the significant improved effect on complex projects duration, budget, and quality performance needs further investigation.

4.3. FURTHER RESEARCH

Further research within this area could address a wide range of issues since the theory and the research area is still relatively unexplored. However, there are some parts of the theory, which seems more relevant and beneficial to study. Some of these are described in the following.

The most relevant and beneficial part to study of this research area is trying to falsify the theory associated to complex projects. The effect of falsifying the theory of proactive pre-planning and its relation to increased project performance, would replace the existing theory by a new and more comprehensive one.

However, if the existing theory associated to complex projects is not possible to falsify, a study trying to falsify individual elements of the improved project duration, budget, and quality performance would be relevant.

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APPENDED PAPERS

Appended papers are the basis of the Ph.D. thesis "Streamlining Publicly Funded Construction Projects by Proactive Planning and Cost Scheduling to Reduce Critical Increases. The enclosed research articles serve therefore as documentation to the presented research findings in the thesis chapter 3 - Results of Research. Listed papers have all been individual published or submitted for review at either topic related international research conferences or journal houses. Repetition of certain sentences or arguments among the listed papers must hence be expected.

List of Appended Papers

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